Unsupervised Learning of Robust Spectral Shape Matching

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Project Page

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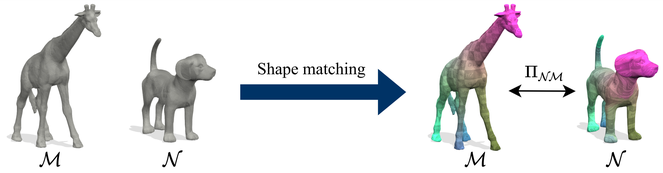
3D Shape Matching



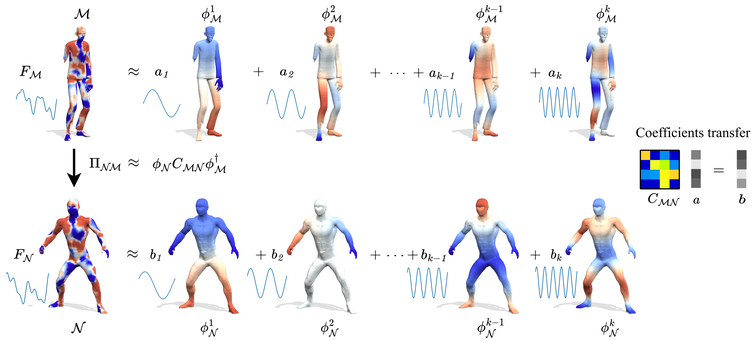
- **Difficulties:** non-alignment, different discretisation, non-isometry, partiality
- **Applications:** texture transfer, deformation transfer, statistical shape models

Our Contributions

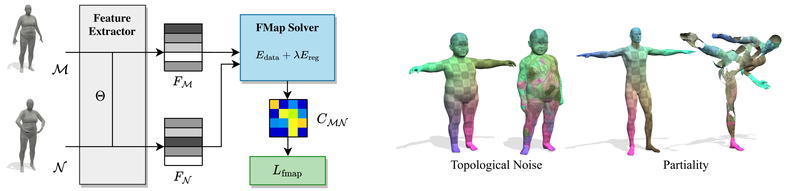
- A novel coupling loss which associates a functional map with a point-wise map
- A shape matching framework that can be applied to a broad range of settings
- New state-of-the-art matching performance on the most challenging datasets

Functional Maps

- Find correspondences in the functional domain by using functional maps
- Encode functional maps in small matrices using the first k LBO eigenfunctions [2]

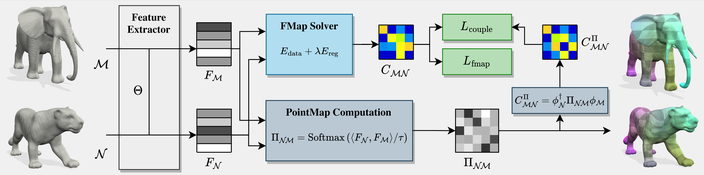


Previous Deep Spectral Shape Matching Pipeline



- Train feature extractor for functional map computation [4]
- Requires post-processing to convert functional maps to point-wise maps [1]
- Large performance degradation for difficult cases (e.g. topological noise, partiality,...)

Our Approach



- Enforce functional map to be associated with a point-wise map
- Replace off-the-shelf post-processing by efficient test-time-adaptation
- Robust in a broad range of challenging settings (see right column)

Coupling Loss Term

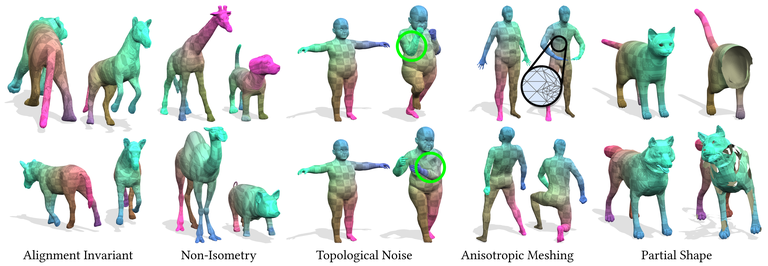
- A valid functional map $C_{\mathcal{MN}}$ should satisfy the discrete constraint [3]

$$\left\{ C_{\mathcal{MN}} \mid \exists\, \Pi_{\mathcal{NM}},\ \text{s.t. } C_{\mathcal{MN}} = \phi^{\dagger}_{\mathcal{N}} \Pi_{\mathcal{NM}} \phi_{\mathcal{M}} \right\}$$

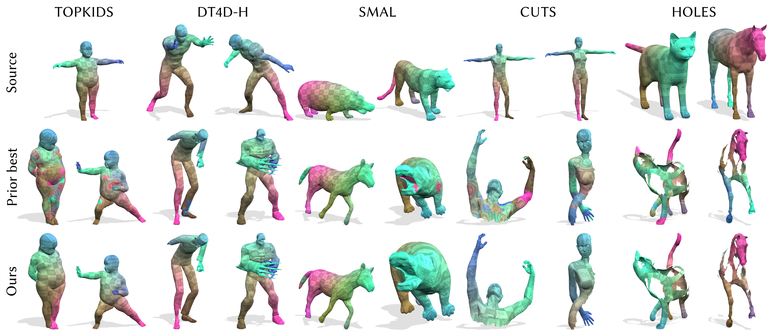
- Instead of formulating the map relation as a discrete constraint, our coupling loss incorporates the soft constraint

$$L_{\text{couple}} = \left\| C_{\mathcal{MN}} - \phi^{\dagger}_{\mathcal{N}} \Pi_{\mathcal{NM}} \phi_{\mathcal{M}} \right\|^2_F$$

Robustness



Experimental Results



Geo. error (×100)	FAUST	SCAPE	FAUST_a	SCAPE_a	SHREC19	TOPKIDS	SMAL	DT4D-H	CUTS	HOLES
Prior best*	**1.5**	**1.9**	2.3	2.2	5.8	13.7	5.4	**4.1**	8.4	17.9
Ours	1.6	**1.9**	**1.9**	**1.9**	**4.6**	**9.2**	**3.9**	**4.1**	**3.3**	**9.1**

* See our paper for the set of considered methods.

References

[1] Simone Melzi, Jing Ren, Emanuele Rodolà, Abhishek Sharma, Peter Wonka, and Maks Ovsjanikov. Zoomout: spectral upsampling for efficient shape correspondence. *ACM Transactions on Graphics (TOG)*, 38(6):1–14, 2019.

[2] Maks Ovsjanikov, Mirela Ben-Chen, Justin Solomon, Adrian Butscher, and Leonidas Guibas. Functional maps: a flexible representation of maps between shapes. *ACM Transactions on Graphics (ToG)*, 31(4):1–11, 2012.

[3] Jing Ren, Simone Melzi, Peter Wonka, and Maks Ovsjanikov. Discrete optimization for shape matching. *Computer Graphics Forum*, 40(5):81–96, 2021.

[4] Jean-Michel Roufosse, Abhishek Sharma, and Maks Ovsjanikov. Unsupervised deep learning for structured shape matching. In *Proceedings of the IEEE/CVF International Conference on Computer Vision*, 2019.

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